The impact of external events on the emergence of social herding of economic sentiment

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Abstract

We investigate the impact of an exogenous environment on the emergence of social herding of economic sentiment. An interactions-driven dynamics of economic sentiment is modeled by an Ising model on a large (two-dimensional) square lattice. The individual states are called *optimism* and *pessimism*. The exogenous environment is modeled as a sequence of random events, which might have a positive or negative influence on economic sentiment. These exogenous events can be frequent or rare, have a lasting impact or a non-lasting impact. Impact of events is inhomogeneous over the lattice, as individuals might fail to perceive particular events. We introduce two notions of social herding: *permanent herding* refers to the situation where an ordered state (i.e. a state with an overwhelming majority of optimists or pessimists) persists over an infinite time horizon, while *temporary herding* refers to the situation where ordered states appear, persist for some time and decay. The parameter of the inter-agent interaction strength is such as to engender permanent herding without the influence of the environment. To investigate the impact of an environment we determine whether an initially ordered state decays. We consider two cases: in the first case positive and negative events have both the same empirical frequencies and strengths, while in the second case events have the same empirical frequencies but different strengths. (In the first case the environment is "neutral"in the long term), In the neutral case we find temporary herding if events are sufficiently "strong" and/or perceived by a sufficiently large proportion of agents, and our results suggest that permanent herding occurs for small values of the parameters. In the "non-neutral" we find only temporary herding.

1 Introduction

Recently, there has been renewed strong interest among scholars of economics in the notion of *consumer sentiment* – a vague concept operationalized in particular surveys as a bundle of consumer expectations and assessments of the economic prospects – on individual and aggregate economic activity [11, 27, 35]. While consumer sentiment has been considered a relevant indicator by practitioners of economic policy [20], economic modeling is primarily concerned with other, more specific types of expectations (such as income and price expectations for a particular point in time), and there is much less agreement among theorists in what way – if any – the concept of consumer sentiment – or, more generally, the concept of economic sentiment – should enter economic modeling.

The basic assumption of the present paper is that economic sentiment is prone to imitative social influence, in that, say, a consumer is more likely to hold an optimistic (pessimistic) expectation about the economic prospects if the peers do. That assumption is well substantiated: according to experimental social psychology, an individual is the more likely to conform to the judgment of others the less (s)he is able to form an own judgment in a rational and informed manner [1, 2, 13]. Since experimental studies in the human perception of complex dynamic systems [16, 36] suggest that a typical consumer has only a limited perception about the functioning of the economy and the political system in which it is embedded (arguably, this limitation applies to a considerable extent even to specialists), one is indeed led to the conclusion that the formation of economic sentiment is prone to social imitation. Social imitation of consumer sentiment might or might not result in herding of economic sentiment at the macroscopic level. The conditions for the emergence of sentiment herding at the macroscopic level are investigated for a particular model in the present paper.

The general phenomenon of social herding has attracted much interest in economic theory over the last two decades, particularly in the wake of disturbances on financial markets (see [3, 5, 25, 26, 29, 6] for some seminal contributions). A principle question in models of social herding is whether or not individual behavior should be derived from the principles of economic rationality. The first two of the above cited papers do so. Our paper does

not, as it is based on the *statistical modeling approach*[1] which directly applies to sentiment formation the empirical evidence of *social comparison* processes (see [1, 2, 13]) rather than explaining economic sentiment formation from rationality principles. We believe that the statistical approach is particularly appropriate for modeling the dynamics of economic sentiment because economic sentiment, if considered as a particular instance, or at least part, of a consumer's *mental model* [8, 33], is a premise of individual reasoning and decision-making rather than the subject of it. Most directly, our present paper belongs to the recent literature on socially-driven economic sentiment formation [14, 21, 12, 37, 38].

The aim of this paper is to investigate the impact of an exogenous environment on the emergence of social herding of consumer sentiment. Indeed, economic traders react as much to the news coming from the broader geo-political environment – whether or not these news items are objectively interpreted – as to the behavior/advice of others. Consumer sentiment subject to social imitation is modeled in our paper as a large Ising field with nearest-neighbor interactions on a (two-dimensional) square lattice. The individual states are called *optimism* and *pessimism.* Social herding corresponds to the emergence of coordination states of the Ising model, i.e. states with predominantly optimistic or predominantly pessimistic individual entities. The environment is modeled as a a sequence of exogenous events (external influences), stochastically fluctuating over time. The exogenous events can be frequent or rare, have a lasting impact or a non-lasting impact. The field of events is not homogeneous, as individual actors might fail to perceive events. Though the environment does have an impact in existing models of financial herding, for instance in chartists-fundamentalists models [25, 29] as changes in the fundamental value, or as news affecting traders [30], our model – due to its simple abstract structure – is particularly suitable for analyzing the interplay of social (local) interactions and environmental (global) influences in a more abstract way suitable for computer simulations. [2]

Motivated by our results, we introduce two notions of social herding in our model: *permanent herding*, the stronger notion, refers to an ordered state (i.e. a state with an overwhelming majority of optimists or pessimists) which persists over an infinite time horizon, while *temporary herding* refers to a state in which ordered states appear, persist for some time and

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[1] See [15, 31, 19] for early formulations of the statistical modeling approach in economics and sociology.

[2] In socio-economic applications of the Ising model, an external environment has been previously considered by [19, 18, 22]. Relatedly, there has been much interest recently in the more general issue of disentangling endogenous and exogenous dynamics in complex systems [9, 34].

decay. The parameter of the inter-agent interaction strength in the underlying Ising field is such as to engender a persistent ordered phase of the infinite model (permanent herding in our terminology) *without* the influence of the environment. To investigate the impact of an environment we determine whether an initially ordered state decays for the two cases that positive and negative events have both the same empirical frequencies and strengths (i.e. the environment is "neutral" in the long term) and that the latter property does not hold. In the neutral case we find temporary herding if events are sufficiently "strong" and/or perceived by a sufficiently large proportion of agents, and our results suggest that permanent herding occurs for small values of the parameters. In the "non-neutral" case we find only temporary herding.

In the present paper we concentrate on the interplay of endogenous and exogenous influences on economic sentiment, neglecting its link with real economic variables. We do so because that link has not been investigated at the behavioral level; see [12, 37, 38], however, for attempts to account for that link in similar or related models).

2   The model

We let the Ising model on a two-dimensional square lattice with nearest-neighbor interactions represent socially-driven collective dynamics of economic sentiment.[3] The variable x_i denotes the economic sentiment of agent i. Individual states $x_i = -1$ and $x_i = 1$ represent the individual states of pessimism and optimism respectively. It is well-known that for interactions between agents stronger than some critical value J_c (leaving aside any external influences) there exist on the infinite lattice two phases of the sentiment field ("coordination states"), with the economic actors in each of them being either predominantly pessimistic or predominantly optimistic [10]. These phases are stable states which emerge – in an appropriate formal sense – already in a large enough finite system [23] ("permanent herding" in our terminology).

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[3]We must point out the limitations of our basic model. First, the topology of social interactions is hardly as simple as a square lattice, yet we are not aware of empirical investigations of network structures for our particular subject of social interactions, and network structures found for other contexts (see e.g. [4]) are not necessarily transferable to our context [32]. Second, interactions need not be symmetrical with respect to the individuals involved, as is the case in our model. Third, the individual states of economic sentiment should be more rich, possibly even continuous. However, we do believe that the Ising model provides a first approximation to the type of systems we aim to analyze.

The events affecting consumer sentiment ("the environment") at a given point in time are modeled in the present paper as realizations of a random variable B with the possible values $B = b$ ("positive" event), or $B = -b$ ("negative" event), or $B = 0$ (no event) in the case of a neutral environment, and $B = -2b$ ceteris paribus in the case of a biased environment. We assume an agent perceives the event correctly with probability p, while ignoring the event with probability $1 - p$. Perception of an event is independent among agents. We introduce a variable ϵ_i such that $\epsilon_i = 1$ represents the situation that agent i perceives the event and $\epsilon_i = 0$ that he does not.

According to principles of statistical modeling, the following interaction potential[4] appropriately characterizes the interaction structure of our model in a finite square lattice Λ

$$H(x) = -\frac{J}{2} \sum_{i,j \in \Lambda: ||i-j||=1} x_i x_j - B \sum_{i \in \Lambda} \epsilon_i x_i, \tag{1}$$

with periodic boundary conditions specified in our simulations. The strictly positive parameter J characterizes the interaction-to-noise ratio. The first sum accounts for local interaction between individual agents, while the second accounts for the impact of the exogenous events.

In Monte-Carlo Statistical Physics equilibrium states are obtained from an appropriate algorithm (which can be interpreted as a stochastic dynamics of the system), whereby individual sites are sequentially updated according to the probabilities proportional to $\exp(-H)$, using the prevailing configuration of next-neighbors. In doing so, we use the following specifications of the process B_t representing the environment: external events can be frequent (time scales of the Ising field and the external field are comparable) (see Figure 1, top), lasting but rare, (e.g. the environment may change only once in T updates of all individual variables) (see Figure 1, top), and rare transitory (i.e. shocks; see Figure 1 bottom). Positive and negative events/shocks occur equally frequent (on average) in all cases.

3 Results

Figure 2 summarizes our simulation results on the persistence of an initial ordered state of the consumer sentiment field for the case of a large system and a neutral environment. The curves in Figure 2 separate areas of the parameter space – the parameters being the

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[4]In physics, Eq. 1 has the interpretation of energy, and the sum of individual energy contributions is called Hamiltonian, and the model is the Ising model. In social sciences, we do not have a quantity corresponding to energy, such that Eq. 1 is merely a representation of interactions between people and events.

proportion p of agents perceiving the event[5] and event "strength" b – for which the initial ordered state persists over 4000 Monte Carlo time steps (these areas are below a curve), and in which the initial ordered states do not survive over 4000 MCTS (these areas are above a curve). For a fixed b, the proportion p was diminished until for half of the four simulated samples no change from the initial optimistic majority to a slight majority of pessimists was observed during 4000 iterations (sweeps through the lattice). This border point then was put into Fig.2.

As 4000 is a somewhat arbitrary time scale, we also investigated stability of an initial ordered state over very long times for frequent news and $J_c/J = 0.9$. Figure 3 depicts the dependence on p of the median time at which the ordered state is destroyed for a fixed exemplary value $b = 1$. It turns out that this time tends to infinity for $p \simeq 0.16$, close to the corresponding $p \simeq 0.20$ for 4000 iterations in Figure 2. This suggests that there is an area of the parameter space (presumably separated by a curve running slightly below the curve in Fig. 2) for which an ordered state is stable over infinite time horizons for a very large lattice. (Small lattices do not have sharp transitions.) In this case, the environment does not have a destructive impact on collective consumer sentiment.

What are the properties of the model for parameters b and p above a curve in Fig. 2? The inspection of figures displaying time-paths of the proportion of optimists/pessimists for parameter values above a curve in Fig. 2 (available from the authors on request) shows that the typical time-path above a curve in Figure 2 is irregular: Periods of collective pessimism emerge, persists for some time and decay, as do periods of collective optimism. Periods of collective pessimism and optimism change much more slowly than the exogeneous environment, thus collective pessimism (optimism) often persist while and despite positive (negative) events occur. Periods of collective pessimism and optimism occur – as positive and negative events – equally frequently over time for the neutral environment.

These results lead us to introduce two notions of social herding in our model: *permanent herding*, the stronger notion, refers to an ordered state (i.e. a state with an overwhelming majority of optimists or pessimists) which persists over an infinite time horizon, while *temporary herding* refers to a state in which ordered states appear, persist for some time and decay. (Note that the parameter of the inter-agent interaction strength in the underlying Ising field is such as to engender a persistent ordered phase of the infinite model – permanent herding in our terminology – *without* the influence of the environment.) Thus, for the

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[5]Clearly, for large enough systems this fraction equals the probability p of an agent perceiving the event.

neutral environment, our results strongly suggest that permanently stable ordered states of collective pessimism/optimism do not occur if events are too strong and/or are considered by a sufficiently large proportion of agents. This is due to a "competition" between the social mechanism tending to produce coordination, and the disorder of the external environment. Given that positive and negative events have equal empirical frequencies, such that the environment is "neutral" with respect to sentiment, it is quite intuitive that a widespread perception of external events destroys endogenous collective states: the disorder of the environment then prevails over the tendency to herding in economic sentiment.

We also considered an environment which is biased in favor of pessimism. We take the strength of negative event as $-2b$, i.e. twice as strong as the positive event b. Analogously to Fig. 2, the curves in Figure 4 separate areas of the parameter space in which the initial ordered state persists for a simulation length of 4000 Monte Carlo time steps (these areas are below a curve), and in which the initial ordered states does not survive over 4000 MCTS (these areas are above a curve). Fig.4 shows that the b or p values required for this transition are now drastically smaller than for the neutral environments in Fig.2. Analogously to Fig.3 we show in Fig.5 the variation of the median destruction time, but now for this biased case of Fig.4. Roughly the data follow a straight line on this log-log plot, suggesting a finite decay time for all finite p, going to infinity for $p \to 0$ only. We see upward deviations for small p but the larger the lattice is the smaller are these deviations. Thus in the biased case, in contrast to the unbiased one, the initial order is always destroyed if we only wait long enough.

4 Discussion

States of "collective pessimism" – if this social phenomenon indeed occurs – might be detrimental to the efficiency of allocation of economic resources. Indeed, "explanations" to that effect can often be heard in the public discussion about the state of the economy and economic policy. We believe that economic-sentiment-based arguments are relevant despite the lack of proper theoretical foundations, and the present paper is an exploratory step toward formulating relevant models. Our results confirm an intuitive presumption: attention to news reduces the prevalence of collective economic sentiment. This result appears to suggest that our model might be a useful starting point, though the present paper does not cover several important issues. In particular, the role of the graph structure of the underlying

network should be investigated. Also, we have not specified the actual "transmission mechanism" of economic sentiment into economic variables necessary for a welfare analysis of the impact of collective economic sentiment.

A more general problem lies in the fact that what we called environment is only in part exogenous, as the economy itself produces relevant news which is interpreted by the decision-makers – albeit not necessarily in a correct way. For instance, prolonged investor pessimism might lead to a reduction of GDP, which in turn negatively affects investor sentiment. Such collective expectational biases turning into real economic forces have been qualitatively described by Keynes [24], but are largely neglected in modern macroeconomic theory. (In contrast, recent modeling of financial markets does incorporate expectational biases (see [28, 29] for seminal contributions to this research direction). The present model does not include a feedback from real macro-variables ("endogenous environment") to the economic sentiment (see [38] for an attempt in this direction) as we do not specify a link of economic sentiment to real variables.

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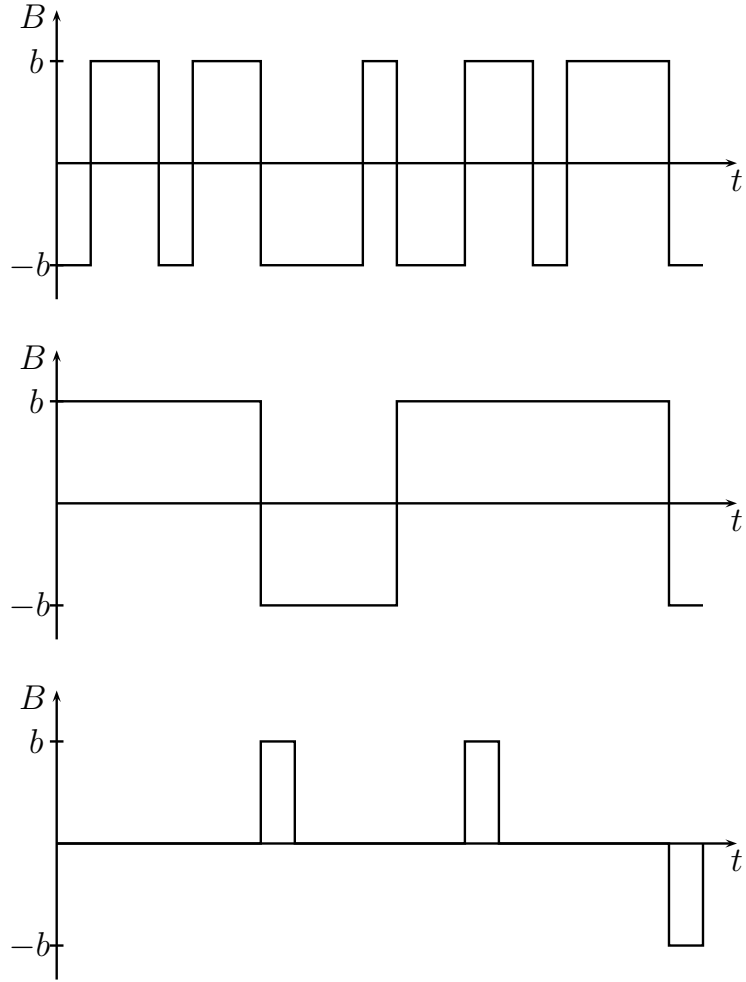
Figure 1: Time-patterns of the process B_t representing the environment: time scales of the Ising field and the external field are comparable (top), lasting but rare events (middle) and rare transitory events (shocks) (bottom). The proportion of positive and negative events is equal on average for the neutral environment.
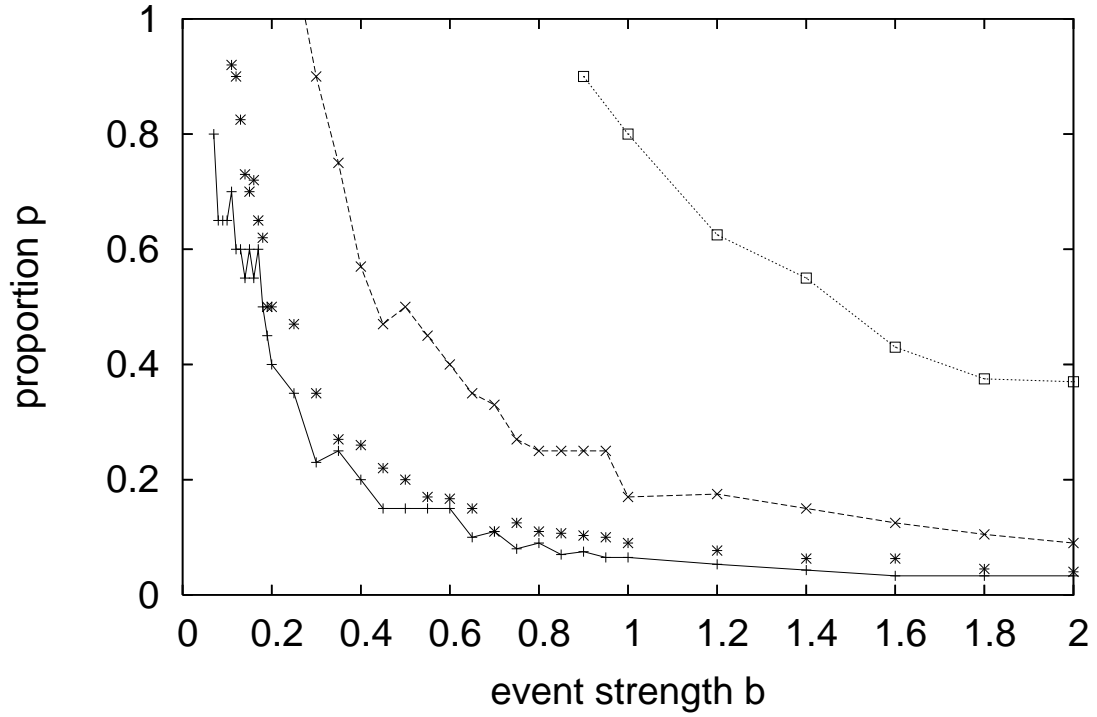
Figure 2: Areas of the parameter space of our model where ordered states persist and do not persist for a neutral environment for 4000 sweeps through a 3001 x 3001 lattice: ordered states of collective sentiment exist for vectors of the parameter values below a boundary curve, but do not exist for vectors of parameter values above; the curves are as follows: $(+)$ frequent events, $J_c/J = 0.99$, $(\times)$ frequent events, $J_c/J = 0.9$; $(*)$ rare persistent events, $J_c/J = 0.9$, (sq.) shocks $J_c/J = 0.9$.
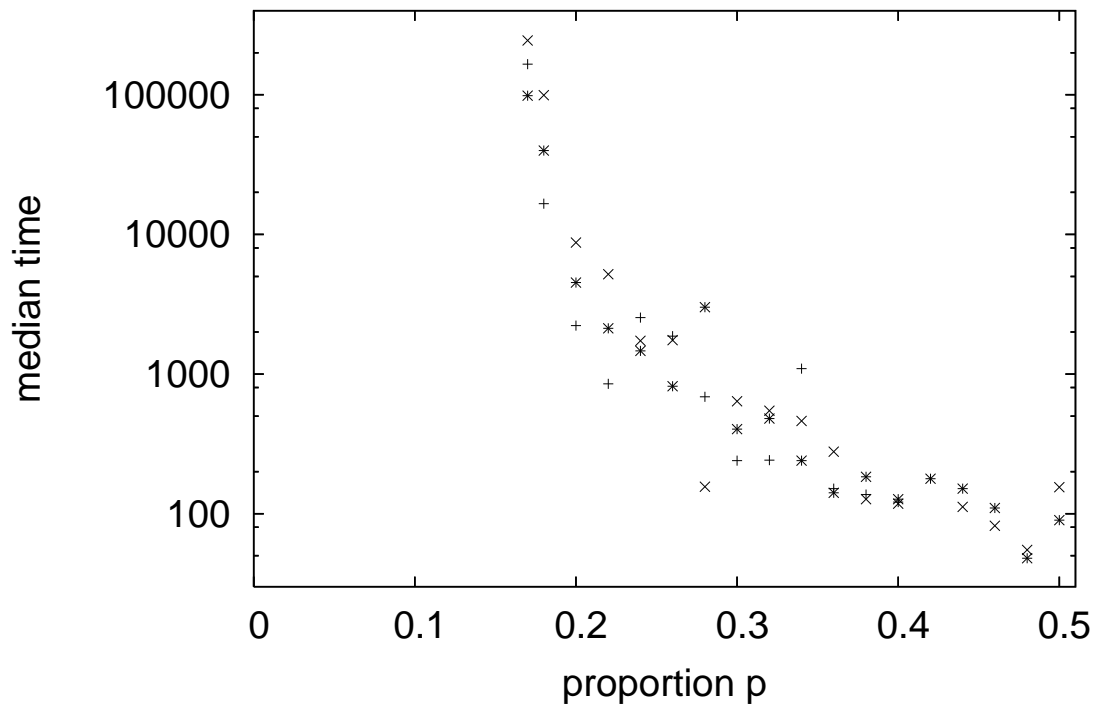
Figure 3: The dependence on p of the median time at which the ordered state is destroyed for the exemplary value $b = 1$; frequent events, $b = 1$, side of the square lattice $d = 301(+)$, $1001(\text{x})$, $3001(*)$.
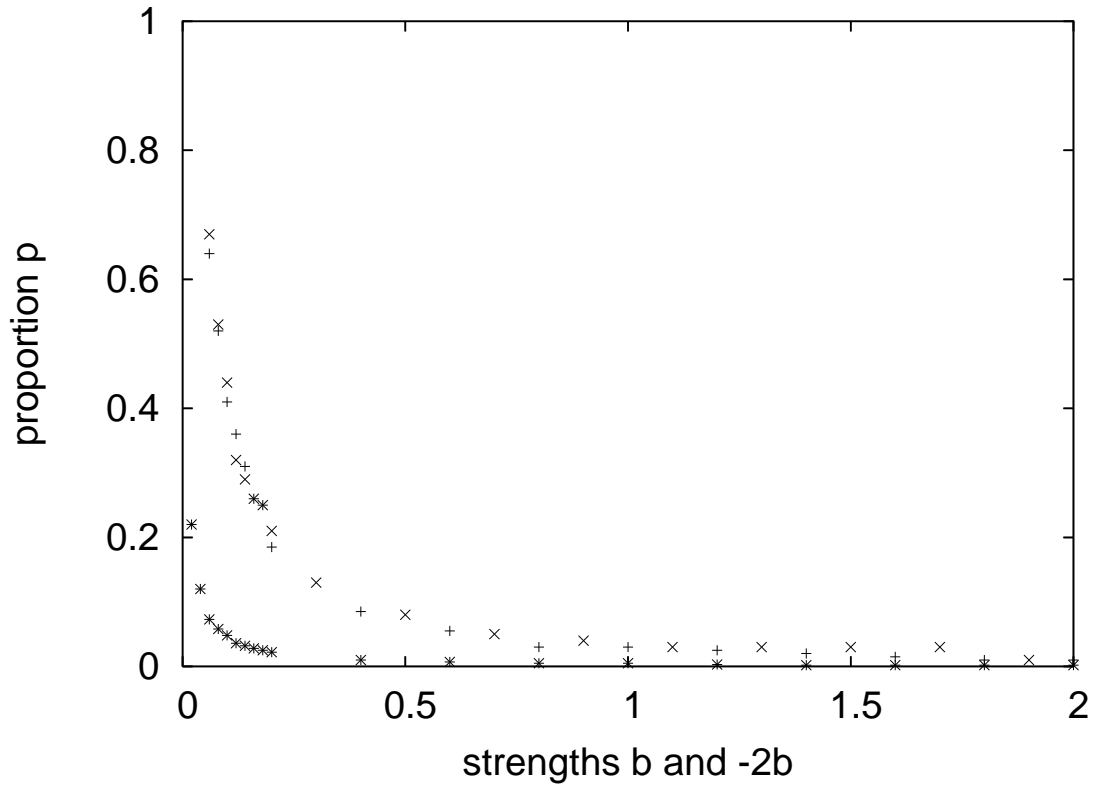
Figure 4: As Figure 2, but for biased (non-neutral) environment. We made 4000 sweeps for $J_c/J = 0.90$ (+,x) and 0.99 (*), for frequent events only, for 1001×1001 (+) and 3001×3001 (x,*) lattices. For 1001×1001 at $J_c/J = 0.99$ the symbols would overlap with those for the larger lattice and are thus not shown.
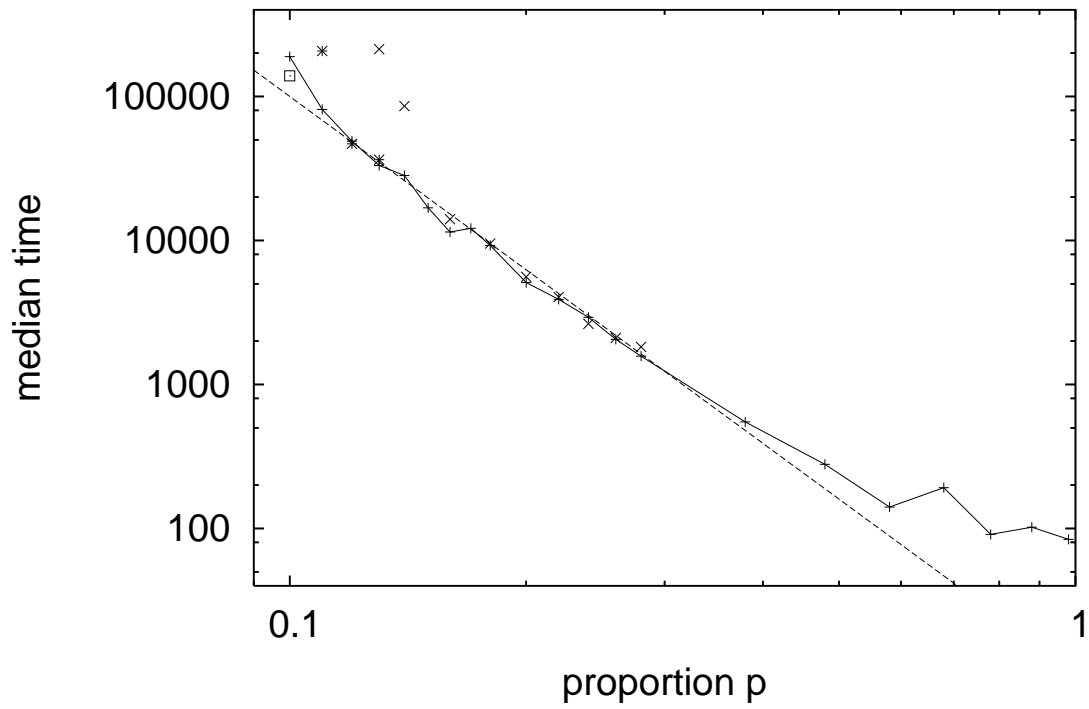
Figure 5: As Figure 3, but for biased (non-neutral) environment. The side of the square lattice d is 301 (+), 1001 (x), 3001 (solid line) und 10,001 (square). The dashed line corresponds to a power law time $= 10/p^4$.